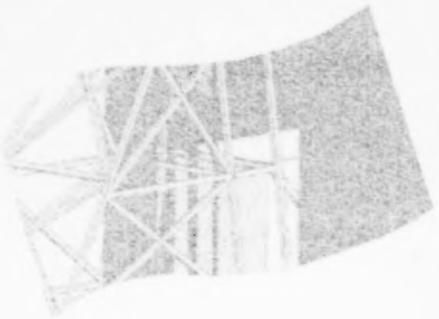
Safety of mine hoists controlled by programmable systems



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TECHNICAL GUIDE

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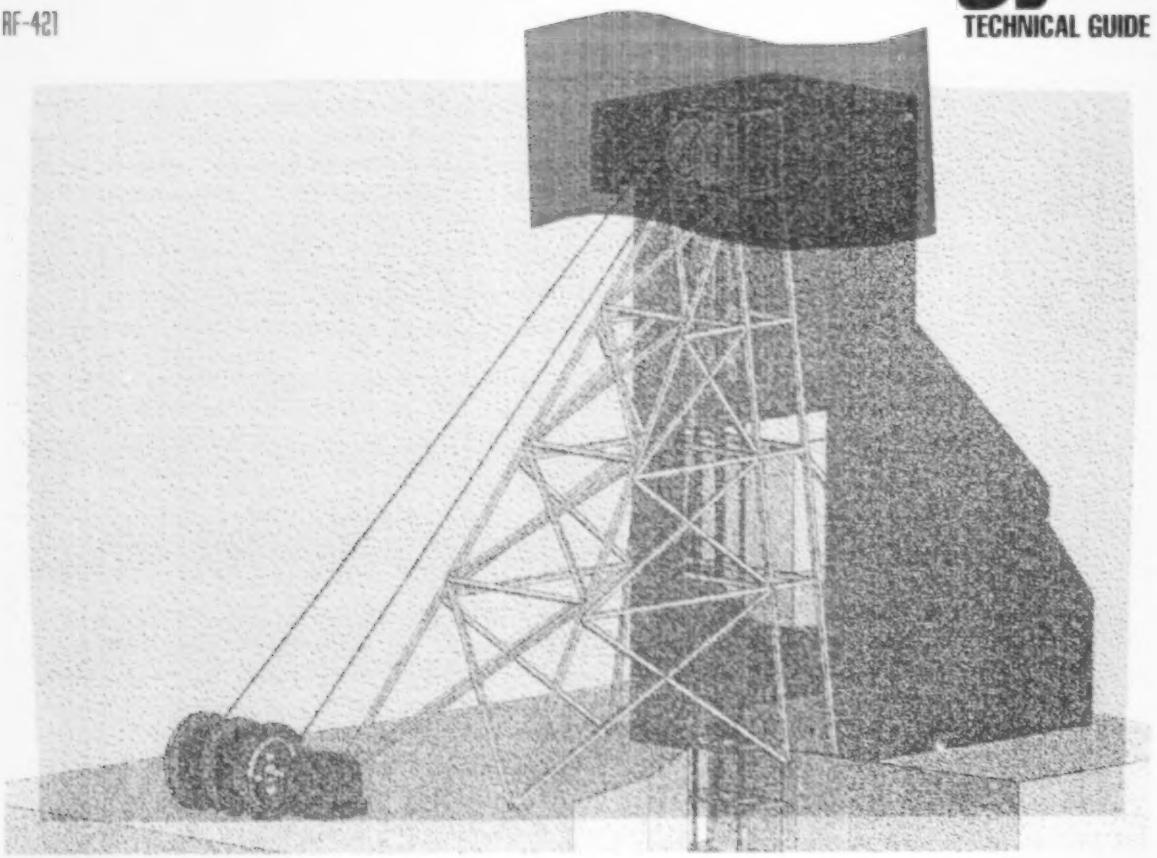

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Safety of mine hoists controlled by programmable systems

STUDIES AND RESEARCH PROJECTS

TECHNICAL GUIDE

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1 INTRODUCTION

Notice: *This guideline replaces the guideline "Safety of Mine Hoists Controlled by Programmable Systems", RF-267, published in July 2001 as an experiment; its content is the result of the testing of the previous safety data sheet and consultation with its users.*

1.1 Definitions

The guide on mine hoists [1], based on the regulation on safety in Québec mines [2], provides information for those interested in the operation of mine hoists. It presents the different safety mechanisms and provides the necessary information for ensuring that the machines operate properly. At the time the guide [1] and regulation were being prepared, programmable control technologies were still not readily available. With the rapid evolution in new technologies and the desire for cost-effective investment, **programmable control systems (PCS)** were progressively implemented in all industries. The mining sector did not escape this trend and several Québec mines equipped their hoists with such systems. However, it is clear that the introduction of these new technologies, necessary for improving Québec mining productivity, must not contribute to and increase the level of risk.

It should be remembered that the expression **programmable control systems**, whose French and English acronym is **PES** [3], consists of several computer-based **programmable electronic technologies (PE)** that can include equipment, software, as well as data input or output units. This terminology covers microelectronic devices based on one or more central processing units (CPU) related to memory, etc. For example, all of the following components are programmable electronic devices:

- microprocessors;
- microcontrollers;
- application specific integrated circuits (ASIC);
- programmable controllers (PC) or programmable logic controllers (PLC or IPC);
- the other devices based on computer technology (for example smart sensors, transmitters, actuators, speed controllers, cycloconverters, etc.).

Programmable electronic systems are themselves defined [3] as **control, protection or monitoring systems** comprised of one or more **programmable electronic** devices. This term covers all the elements in a system of this type, including power supply, sensors or other input devices, as well as actuators or other output devices, and including data highways and other routes of communication.

1.2 Reliability of PES

From the safety standpoint, and as mentioned in INRS Note documentaire no. 117 [4], programmable controllers have three main characteristics that are different from those of the previously-used electromechanical technology-based controllers:

---

1 FORTIN, G., Demers, R. *Les machines d'extraction, Guide*, Commission de la santé et de la sécurité du travail du Québec, 1993.

2 *Regulation respecting occupational health and safety in mines*, S-2. 1, r. 19.1, Gouvernement du Québec, 1998.

6 *Sécurité fonctionnelle : systèmes relatifs à la sécurité, Partie 4 : Définitions et abréviations*, Commission électrotechnique internationale, Comité technique n° 65 : Mesure et contrôle du procédé industriel, IEC 61508-4, 53 pages, 1998.

4 VAUTRIN, J.-P., Dei Svaldi, D.,*Les automates programmables : Nouvelles technologies, nouveaux risques, principes de sécurité à appliquer*, Institut national de recherche en décurité, Cahiers de notes documentaires, ND 117, 1984.

- The programmable controller's failure modes are not well known, and furthermore, their behavior on internal failure cannot be predicted.
- Conducted or radiated electrical interference can produce extreme perturbations (particularly from the radio-communication systems used in mines).
- The possibility of rapid modification of programs offers a flexibility that may introduce additional risks.

INRS note documentaire no. 117 [4] then recommends that the rules below be followed: (free translation)

With current knowledge:

1) Direct safety functions must not be taken into consideration solely at the programmable controller. Even if the safety data (emergency stop, protectors) can be input data for the controller, it must necessarily act directly on the actuators. In other words, direct safety must not be basically dependent on the expected proper operation of the controller.

2) If controllers are to be used, regardless, to ensure direct safety, specific solutions must be implemented (dynamism, doubling of controllers). The safety level achieved must also be as high as in positive safety hard-wired logic. In particular, a failure must not result in a hazardous situation. In the case where doubling of the controllers is chosen, common failure modes affecting the two channels must be scrupulously eliminated.

3) Indirect safety functions (self-checking functions, synchronism, controls) can be performed by cabled logic or programmed logic, with both complying with accepted practices.

This restriction relating to the safety applications of programmable controllers also appears in the note to paragraph 11. 3. 4 of IEC 61204-1[5] "In situations where a significant hazard can occur due to maloperation of the control system, it is currently difficult to determine with any degree of certainty that reliance on correct operation of a **single-channel** of **programmable electronic equipment** can be assured. Until such a time that this situation can be resolved, it is inadvisable to rely solely on the correct operation of such a single-channel device."

1.3 Risk analysis

The process that led to the current recommendations on control and monitoring systems that use programmable technologies is identical to the one that was carried out to establish the regulation [2] as well as the guide [1] on the safety of mine hoists. The latter was based on an informal risk analysis, developed from the experience of users, manufacturers and CSST inspectors, and that led to a certain number of recognized solutions being prescribed. In preparing this guideline, this non-formalized analysis process was extended to mine hoist control and monitoring systems that use programmable technologies, while referring to experiences in the mining environment when available, and to experience in other applications of programmable control technologies in other types of industries, often put into concrete form as specific standards.

5 *Équipement électrique des machines industrielles - Partie 1: Prescriptions générales*, Commission électrotechnique internationale, CEI/IEC 204-1, 1997.

Although the need for a more global and more formalized process for analyzing the risks associated with mine hoists is felt, general standards now exist for machine hazard analysis [6], as well as control system safety [7] and machine safety in general [8 and9], which can be consulted.

1.4 Use of the guideline

This guideline is intended for users and installers of PES-controlled mine hoists. It in no way changes the basic safety requirements of the regulation and the guide (1). It provides additional information on the objectives to be achieved in terms of the safety of PES-controlled mine hoist systems. This document is provided for information purposes only and does not exempt the designer or user from having to comply with all the legal or regulatory requirements related to their operations.

The guideline's recommendations mainly cover the general structure of control and monitoring systems of PES-controlled mine hoists, on its specific aspects, and on the periodic tests and checks.

Application of the guideline should ensure that the current safety level of mine hoists is maintained when these machines are controlled by PES.

When the configuration of the control of a mine hoist includes a control PES combined with a mechanical speed controller, such as a "Lilly", the guideline applies integrally, except in the event of a technical impossibility that this configuration may introduce.

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6 *Sécurité des machines. Principes pour l'appréciation du risque*, Norme européenne EN 1050, novembre 1996, (ISO 14121).

7 *Sécurité fonctionnelle : systèmes relatifs à la sécurité, Parties 1 à 7*, Commission électrotechnique internationale, Comité technique n° 65: Mesure et contrôle du procédé industriel, IEC 61508-1/7, 1998.

8 *Sécurité des machines, Notions fondamentales, principes généraux de conception - Partie 1: Terminologie de base, méthodologie*, Projet de norme internationale, ISO/CD 12100-1 : 2003.

9 *Sécurité des machines, Notions fondamentales, principes généraux de conception - Partie 2 : Principes et spécifications techniques*, Projet de norme internationale, ISO/CD 12100-2 : 2003.

2 GENERAL STRUCTURE OF CONTROL AND MONITORING SYSTEMS FOR MINE HOISTS CONTROLLED BY PROGRAMMABLE SYSTEMS

2.1 General principles of the structure of the control and monitoring system

This document's recommendations in no way modify the general structure of control and monitoring systems for mine hoists installed in Québec. Regardless of the technology used to produce these systems, the general principle is still a total separation between the basic control functions and monitoring functions in the proper operation of the installation. The prescribed periodic tests complete this principle by enabling the operator to ensure that operational, mechanical, electrical and electronic safety is maintained.

The general structure of control and monitoring systems for a PES-controlled mine hoist is shown in Figure 1 of the Appendix. It contains the following main components:

2.2 Control PES

The control part acts on the power commutation equipment, thus allowing the speed of the hoist to be varied. In almost all cases, the control equipment regulates the speed.

When a PES is used, the normal speed permitted is automatically limited by the encoders in relation to the remaining distance between the conveyance and the limits of travel, due to encoders.

The motor control acts on service brake release in normal operation (safety circuit "On"). The control PES opens the safety circuit following the initiation of one of the following failures (incomplete list):

- motor and electrical network protection;
- various types of temperature protection;
- brake protection;
- limits of travel protection;
- rope protection;
- operation and indicator protection;
- shaft sinking protection.

The safety devices for PES-controlled hoists can result in four types of action:

Type 1: Immediate stopping of the machine by opening the safety circuit (emergency braking).

Type 2: Automatic stopping of the machine by the driving power (dynamic braking) and once stopping has occurred, opening of the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset). This stopping can occur anywhere on the path of the conveyance.

Type 3: After normal stopping of the machine at its destination, opening of the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset).

Type 4: Alarm to the hoistman indicating the potential problem detected, without initiating stopping.

2.3 Safety circuit

The components of the safety circuit should use a proven technology, such as electromechanical relays, push buttons and direct wiring, so that any opening of the electrical circuit (wire, failure of a coil, etc.)

results in the machine stopping.

Opening of the safety circuit results in the suppression of the power supply to the hoist motor and causes emergency braking.

When the protection initiation signals originate from the PES control or monitoring part, they should be generated through at least three outputs, with two supplying two independent relays, and the third being used for activating the external timer (see 3. 1. 3). These three relays are then an integral part of the safety circuit, and the hoist cannot be reset if their active contacts are not in the off position (self-checking of contact movement).

The following safety signals must be directly wired to the safety circuit with sturdy contacts:

- The overwind switch and its backout switches;
- The overload relay for the D.C. loop if it is not connected to the control PES;
- The emergency stop switches at the manual controls;
- Failure of the monitor (two relays and one external timer) (see note 10);
- Failure of the control (two relays and one external timer).

2.4 Emergency brakes

This device is activated electrically by the safety circuit. Should the latter open, the emergency brakes are then applied. They are applied by their own devices prior to the opening of the safety circuit. This circuit's contacts, which supply power to the solenoid valve coils, must have sufficient capacity to supply the current required by the emergency brakes.

2.5 Power stages of motor

Power can be supplied in several different ways to a hoist motor, primarily to vary its speed. Power semiconductors are being increasingly used in conjunction with microprocessors dedicated to this specialized application.

Improper operation of the power stages must result in the immediate opening of the safety circuit as well as a primary circuit breaker and/or a circuit breaker on the DC loop (*loop breaker*). In all cases, energy should only be transmitted to the motor when the safety circuit is closed.

The opening of the safety circuit due to a problem unrelated to the power stage may, for a period of less than one second, maintain the energy in the motor in order to avoid acceleration of the conveyance.

2.6 Monitoring PES

The speed monitoring system, sometimes called the speed controller, can be mechanical, electronic or a combination of the two. More than 60% of the mine hoists in Québec have been equipped with **monitoring PES** since 1993.

The role of a monitoring PES is to immobilize the hoist by using a type 1 stop (immediate stopping of

10 In the case of a hoist equipped with a control PES combined with a mechanical speed controller such as a "Lilly", direct connection to the "monitoring default (two relays and one timer)" emergency circuit will be replaced by overspeed switches and by lower limit of travel switches.

the machine by opening the safety circuit).

The protection normally performed by a monitoring PES is mainly:

- overspeed in the entire shaft;
- limits of travel in the shaft;
- auxiliary overwind ;
- and various other types of protection.

3 SPECIFIC ASPECTS OF CONTROL AND MONITORING SYSTEMS ACTIVATED BY PROGRAMMABLE SYSTEMS

3.1 General principles to be applied

Note: The general principles presented below have been taken either from existing and validated practices for PES used with mine hoists, or from mandatory recommendations for PES that comply with IEC 61508-2 [11] or from general recommendations on IPC and safety [12].

Any PES or component of a PES that controls or monitors a mine hoist must comply with the following general principles:

3.1.1 Channel separation

The first principle to apply is the complete separation of the hoist's main control system and monitoring system, including the measuring devices (sensors and transmitters), and up to the input of the power actuators (brakes and power equipment), and excluding the actuators themselves. One encoder per drum and one checking encoder must be supplied and used.

3.1.2 Protection against environmental influences

3.1.2.1 Power supply

The control and/or monitoring system must be protected against any variation, drop in voltage and power surges. For example, any increase or drop in voltage in the control or monitoring circuits must be detected sufficiently early so that the internal states can be stored in nonvolatile memory if necessary, and all the outputs can be brought to safe positions, or a backup power unit can be connected [A. 8 of note 11].

3.1.2.2 Separation between the power cables and data cables

Power supply cables must be physically separate in order to reduce the effect of power voltage pulses on the control and data cables [A. 11. 1 of note 11].

3.1.2.3 Increased immunity to interference

Specific techniques, such as shielding and filtering, must be used in order to increase the immunity to interference of the control and/or monitoring system caused by electromagnetic interference that may be induced or conducted in the power cables or from signals, or results from electrostatic discharges [A. 11. 3 of note 11].

3.1.2.4 Protection against the environment

It is always advisable to ensure that the control and/or monitoring system's installation conditions are acceptable and that they correspond to the manufacturers' recommendations, for example for temperature, dust, humidity, corrosion or emissions of electromagnetic radiation [6.2.8 of note 12].

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11 *Sécurité fonctionnelle : systèmes relatifs à la sécurité, Partie 7 : Présentation de techniques et de mesures*, Commission électrotechnique internationale, Comité technique n° 65 : Mesure et contrôle du procédé industriel, IEC 61508-7, 65A/256/CDV, 3-4-98.

12 PAQUES, J.-J. *Règles sommaires de sécurité pour l'utilisation des automates programmables industriels (API)*. Étude/Bilan de connaissances B-028, Montréal, IRSST, (janvier 1991), 19 p.

3.1.3 External watchdog function

In order to ensure that the program runs normally, a function must be inserted in the program that activates an output from each PES at an interval of less than one second. This pulse output is connected to a timer outside the PES, so that it can be kept active.

The disappearance of pulses opens the safety circuit. In this way, the program cannot stall, either due to a change caused by radiated electromagnetic interference or a sequence looping not detected during the tests.

3.1.4 Cyclical self-checking sequences

The PES output contacts, which are part of the safety circuit, must undergo cyclical self-checking, mainly through the use of electromechanical relays with mechanically linked contacts, as defined in Annex L of IEC 60947-5-1 (13), for example at the start of each reset of the safety circuit.

3.1.5 Protection against changes

3.1.5.1 Protection against physical changes

Changes or manipulations whose consequences could have an effect on the safety of the control and/or monitoring system must be automatically detected, for example by validation of a sensor signal or by technical detection (use of a key switch, systematic tests at start-up, etc.). If a change is detected, an emergency action must be carried out [B. 4. 8 of note 11].

3.1.5.2 Parameterization and programming

The control PES must have the following programming characteristics:

- Its basic programming as well as the system's fixed parameterization will not be accessible by the hoistman;
- Parameterization and calibration will be reserved for clearly identified people and carried out according to procedures that ensure the safety of the modifications made;
- Any change of this type or for maintenance may be done only in protected mode, with a personalized access code or with a procedure with an equivalent level of safety;
- After an intervention using a code, protected access must resume automatically after a certain period of time so that the machine is not maintained permanently in unprotected mode;
- If changes to the program or operating parameters must be done from a remote position, safety measures must be implemented to ensure that these changes have a safety level equal to that obtained if the changes were carried out with the machine in view.

3.1.6 Functional tests

After installation, the control and/or monitoring system must undergo complete functional testing to verify how the specifications have been met. To do this, data that properly characterize normal operation of the system will be introduced. The outputs will then be observed and their responses compared to those indicated in the specifications. Deviations from specifications and indications of incomplete specifications will be documented [B. 5. 1 of note 11].

3.1.7 Reliability of components

Any failure of a system component could result in the hoist stopping; for prevention, the reliability of the components used therefore has a direct impact on the availability of the hoist. It is therefore very

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13 *Appareillage à basse tension – Partie 5-1: Appareils et éléments de commutation pour circuits de commande – Appareils électromécaniques pour circuits de commande*, Commission électrotechnique internationale, CEI/IEC 60947-5-1:2003.

important that the components be chosen with care and that they have maximum reliability.

Also, control and/or monitoring systems must be very capable of withstanding the normal and abnormal conditions that can be expected in this type of installation (removal of a card, partial or total loss of power, environmental conditions, etc.). In particular, the partial or total loss of electrical power must not lead to the loss or modification of a program, parameter or any other data required for the safe operation or maintenance of the hoist and its control system.

3.1.8 Memory

The memory used in control and/or monitoring PES must be permanent or at least provide sufficient data retention after a loss of electrical current to stop movement and bring the hoist to a stable and safe state for the workers.

3.1.9 Communication networks

A monitoring PES must not be connected to any communication network other than that required for its own operation.

In particular, any change in program or operating parameter must preferably be done near the machine or, if necessary, through the hoist-dedicated network.

3.1.10 Protection against anomalies during operation and maintenance

To reduce the risks associated with the use or maintenance of the control and/or monitoring system, instructions containing essential information on system use or maintenance must be provided. In some cases, these instructions will also cover system installation. All the instructions must be easily understood. Diagrams and figures must be used to describe complex procedures or systems.

To reduce operating complexity, the control and/or monitoring system designer must ensure that [14]:
- the need for human intervention is reduced to a strict minimum;
- the required interventions are as simple as possible;
- the potential for damage due to hoistman error is reduced to a minimum;
- the control and signaling devices are designed according to ergonomic principles;
- interfaces with the hoistman are simple, well indicated and can be used intuitively;
- the hoistman does not have too much to do, even during extreme situations;
- training in the intervention procedures is based on the users' level of knowledge.

In the same way, in order to facilitate maintenance and repairs, which are often carried out under difficult circumstances and under pressure due to deadlines, the control and/or monitoring system designer must ensure that:
- Maintenance procedures on control or monitoring systems are as limited as possible, if it is impossible to avoid them completely;
- Sufficient significant and easy-to-handle diagnostic tools are included for unavoidable repairs;
- If diagnostic tools must be created or obtained, they should be supplied on time.

3.1.11 Monitoring profile

The monitoring profile must be introduced manually, by taking into account the deceleration in an

14 *Contrôleurs programmables - Partie 4 : Directives pour l'utilisateur*, Comité électrotechnique international, CEI 1131-4, 1995.

emergency situation under the most unfavorable conditions (at full load descending at high speed and with defective means of braking).

3.1.12 Checkpoint

One checkpoint per drum must be established between the two PES, inside the upper deceleration zone, in order to confirm on each trip, the speed and position of the conveyance at this point. Proper operation of the checkpoint must be checked on each cycle. In the case of a friction hoist, this checkpoint must be installed physically in the shaft.

3.1.13 Calibration of the depth indicator

The encoders installed on the hoist and connected to the PES (control and/or monitoring) are used to obtain the position and speed of the conveyance in the shaft. The number of pulses per drum revolution must be sufficient to obtain a precision of at least 1.9 cm (0.75 inches) in the shaft on the first layer of rope. The pulses accumulated in relation to a known reference point allow the PES to calculate the conveyance's position. Calibration in relation to this reference must be done manually and redone when the difference between the calculated position and the actual position is greater than the extension of the rope at the loading level (difference between the conveyance loaded with ore and empty).

- For friction hoists, the pulses always represent the same distance in the shaft. Calibration can be done from a single fixed point in the shaft other than the checkpoint defined in 3.1.12.
- For drum hoists, the pulses represent a different value depending on the number of layers of rope wound around the drum. Calibration should then be done manually at a known position (normally, the unloading point) and at a second position on another layer of rope (normally, the change point between its first and second layer).

3.2 Optional requirements

To improve the reliability and maintenance of a PES that controls and/or monitors a hoist, the following means are strongly recommended:

3.2.1 Recording of events

The continual updating of work and incident computer files is one means of controlling normal and abnormal operations. With it, any activity can be traced, and later, sources of problems that could affect the reliability or safety of the PES that controls and/or monitors a hoist can be diagnosed. Data on operations or incidents can then easily be archived and printed and used as needed. For example, a monthly systematic analysis of incidents could help prevent major events.

3.2.2 Specific monitoring

PES can be the subject of specific monitoring, proposed by manufacturers. Some examples are the following: monitoring of memory failures, internal watchdog, programmed watchdog, etc.

3.2.3 Bypassing of certain protection functions by the hoistman

Situations could arise in which a type of protection must be bypassed so that the hoist can be returned to its normal position. These situations may include:

- testing of the overwind;
- a door causing an obstruction in the shaft;
- protection of the position of the skip locks;
- lower limit of travel when a permanent bmper is used;
- other types of protection.

In all these situations, bypassing must be done in a predefined context. The context in which the protection must be deactivated must introduce restrictions into normal operation or result in the application of auxiliary safety devices.

3.2.4 Risk analysis

If there is doubt about the preventive measures to be used and if this guideline does not answer all the questions, it is strongly recommended that a complete risk analysis be carried out on the hoist, including the control and monitoring PES, based on the most recent standards [notes 7, 7, 8 and 9].

4 PERIODIC TESTS AND CHECKS

The list of indicated types of protection is as complete as possible. All these types of protection do not necessarily apply to every mine hoist, for example due to technical impossibilities. However, all existing protection on one of these hoists must be tested and checked according to the frequencies indicated. These tests and checks must be entered in a record synthetically, to facilitate follow-up. This record must be easily accessible to the intervening party on site, including the inspectors.

The protection specified in the regulation remains mandatory. A written test procedure for each type of protection is not mandatory but highly recommended. It should be available to the maintenance employees so that they can use it to carry out planned checks. A specialized firm can perform the annual or biannual checks. The operator must be able to show that all the protection for the machine in question is periodically checked.

Reminder: *Safety devices for PES-controlled hoists can result in four types of actions, indicated in the third or fourth column of the following tables (*15 *):*

Type 1: immediate stopping of the machine by opening the safety circuit (emergency braking).

Type 2: automatic stopping of the hoist by the driving power (dynamic braking), and, once stopped, opening of the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset). This stopping can occur anywhere on the path of the conveyance.

Type 3: after normal stopping of the hoist at destination, opening of the safety circuit (the problem that caused the initiation must be corrected before the hoist can be reset).

Type 4: Alarm indicating to the hoistman the detected potential problem, without initiating stopping.

4.1 Motor and electrical network protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Loss of one phase of the main power supply		Once every 2 years	Type 1 action	
Instantaneous motor overloads (short circuit)	Art. 232 (7), 233 (7)	Once every 2 years	Type 1 action	
Delayed motor overloads	Art. 232 (7), 233 (6)	Once every 2 years	Type 1 action	
Drop in voltage in electrical network	Art. 232 (7), 233 (5)	Once every 2 years	Type 1 action	
Sudden loss of field (direct current motor shunt)		Once every 2 years	Type 1 action	

15 The type of stopping for the different types of protection that are not mentioned in the regulation may vary with the mode of operation.

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Ground continuity detector for the hoist's different power supplies		Once every 2 years	Type 3 action	
Loss of hoist's motor torque		Once every 2 years	Type 1 action	
Instantaneous and abnormal overload opening of the direct current loop		Once every 2 years	Type 1 (directly on the safety circuit)	
Failure originating from the power supply to the UPS (*uninterruptible power system*)		Once a month	Type 3 action	

4.2 Temperature protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Temperature of the resistance grids of an alternating current motor		Once every 2 years	Type 4 action	
Cooling air flow for hoist motor(s)		Once every 2 years	Type 4 action	
Temperature of coils of motor(s)		Once every 2 years	Type 4 action	
Temperature of disk brake(s) of the drum		Once every 2 years	Type 4 action	
Temperature of the brake hydraulic circuit		Once a year	Type 4 action	

4.3 Braking protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Normal wear on drum brake pads	Art. 232 (8), 233 (8)	Once a week	Type 3 action	
Pressure available for brake release		Once a year	Type 2 action	
Brake not applied (protection on calipers)		Once a year (see note 16)	Type 1 action	
Braking device not released		Once a year (see note 16)	Type 1 action	
Brake applied before unclutching a drum	Art. 251	Once a week	Type 1 action in certain cases	
Interlocking of application of drum's brake after unclutching (mechanical and electrical)	Art. 251	Once a week	Type 1 action	
Detection device for discrepancy between desired braking mode (slow or fast) and the one applied		Once a year	Type 3 action in certain cases	
Wear on disk brake pads		One switch per week	Type 3 action	

4.4 Limits of travel protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Overwind (track limit)	Art. 232 (2), 233 (2)	Once a week	Type 1 (directly on the safety circuit)	
Upper limit of travel	Art. 232 (3), 233 (2)	Once a week		X
Lower limit of travel	Art. 232 (3), 233 (2)	Once a week		X
Protection of people (auxiliary overwind)	Art. 235	Once a week		X

16 Checking of the logic function only.

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Safety doors (surface) or other obstacles in the shaft	Art. 388	Once a week	Type 2 action	
Device for checking hoist deceleration at the limits of travel in the shaft (- 25% from the start of the retarding zone.)	Art. 237 (3)	Once every 2 years (see note 17)		X
Synchronization of a friction hoist	Art. 236	Once a week	Type 1 action	

4.5 Rope protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Slack in rope		Once a week	Type 1 action in automatic mode	
Conveyance's device for checking the application of safety catches		Once a week	Type 1 action in automatic mode	
Continuous measuring device for the section of rope		According to manufacturer	Type 2 action in automatic mode	
Slipping of the rope on the friction pulley	Art. 237 (1)	Once a week	Type 1 action	
Loop of a tail rope	Art. 237 (2)	Once a week	Type 1 action	

4.6 Operation protection

17 The testing frequency may not be required when the PES performs a routine self-check of the protection in question, for example when the encoders self-check continuously.

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Overspeed outside deceleration zones (people)	Art. 235, 232 (4), 241 (1) a	Once a month (note 18)		X
Overspeed outside deceleration zones (ore)	Art. 232, 241 (1) a	Once a month (note 18)		X
Overspeed at the limits of travel	Art. 241 (1) b	Once a week		X
Too great a difference in the hoist's position and velocity between the control PES and monitoring PES		Once every 2 years (note 16)	Type 2 action	
Wrong direction of the conveyance in relation to the command given		Once every 2 years	Type 1 action or 2	
Wrong direction of the ore load (descending)		Once every 2 years	Type 1 or 2 action	
Emergency power cut-off switch at the hoistman's controls (console)	Art. 232 (1)	Once a week	Type 1 (directly on the safety circuit)	
Emergency power cut-off switch installed underground (loading level or other)		Once a month	Type 1 action	
Protection applicable to the skip equipped with a tipper tub	Art. 330	Once a week	Type 1 or 2 action	
Monitoring of the internal operation of the PES		Once every 2 years (note 16)	Type 1 action	X
Key causing the hoist to stop for a PES program change.		Once every 2 years (note 16)	Type 1 action	X

18 Recording the overspeed margin in the log book.

4.7 Safety circuit reset or interlock protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Joystick in neutral position for hoist reset		Once a week	Prevents reset after emergency stop	
Brake fully applied for hoist reset	Art. 249	Once a week	Prevents reset after emergency stop	
Monitoring of the operation of the relays associated with the emergency circuit		Once every 2 years (note 16)	Type 3 action	

4.8 Shaft sinking protection

Type of protection	Article [S-2.1, r. 19.1]	Proposed inspection frequency	Control PES	Monitoring PES
Crosshead that follows the bucket	Art. 320	Once a week	Type 1 action	X
Checking of crosshead safety arm's position	Art. 320	Once a week	Type 1 action	X
Overspeed in the shaft, beyond the upper and lower limits of travel	Art. 242, 232 (4)	Once a week		X
Lower limit of travel (Max. 2 revolutions of drum)	Art. 230, 233 (2)	Once a week		X
Speed below the lower chairs	Art. 234	Once a week		X

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6 APPENDIX A: BLOCK DIAGRAM OF A PES-CONTROLLED MINE HOIST

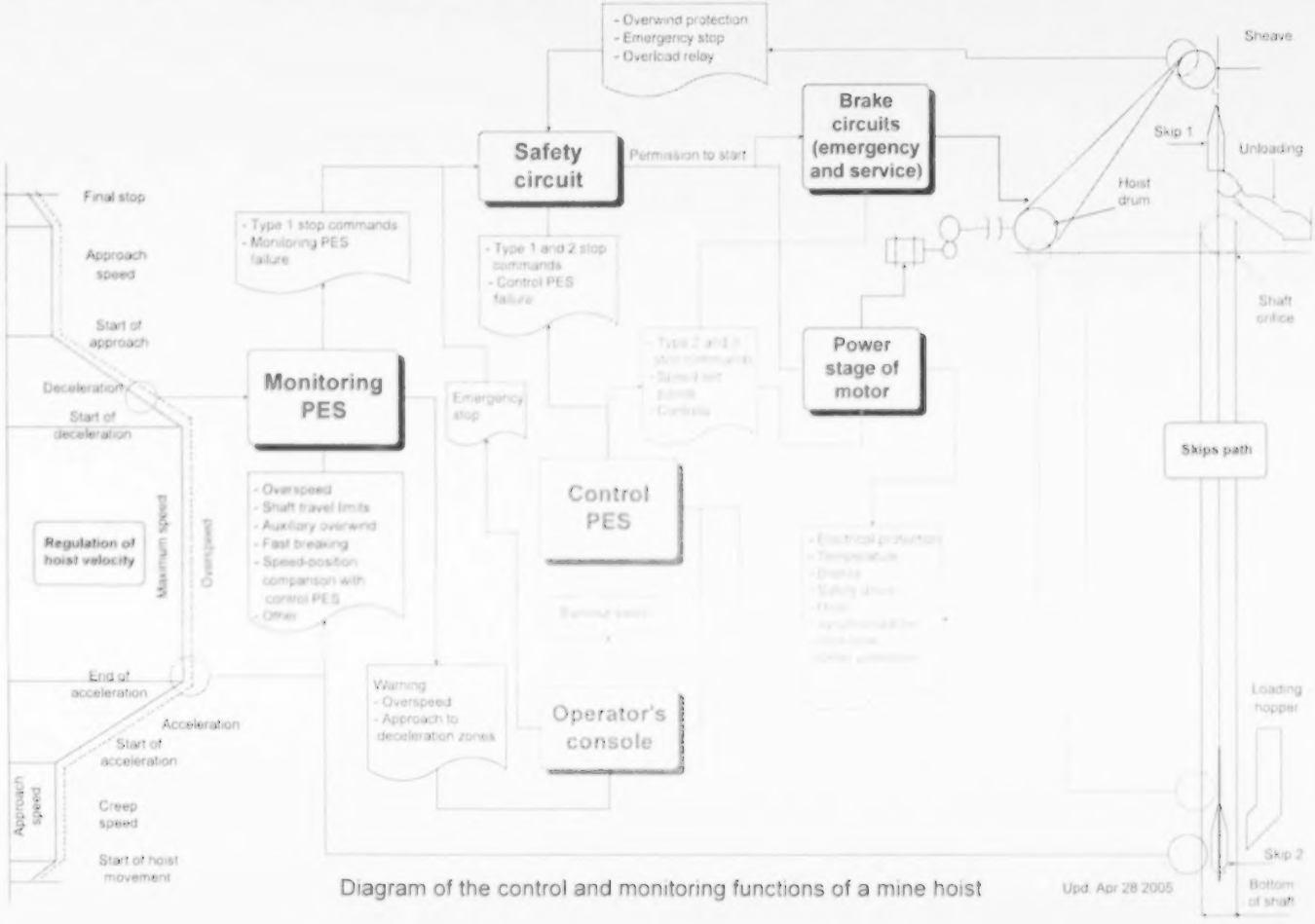

Diagram of the control and monitoring functions of a mine hoist